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Digestibility, N balance and blood metabolite levels in Alpine goat wethers fed either water oak or shining sumac leaves

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Abstract

Eight Alpine wethers (8–9 months of age, 27.5 ± 1.10 kg body weight (BW)) were randomly assigned to consume, free-choice, either shining sumac (*Rhus copallina*) or water oak (*Quercus nigra*) leaves as a sole diet. Leaves were collected and dried prior to feeding. A 14-day adaptation period was followed by a 4-day total fecal and urine collection. Chemical composition (%) of the fed water oak and shining sumac leaves revealed similar levels of OM (95.9 and 94.1) and N (1.54 and 1.42) but higher concentrations of cell wall fractions, NDF (54.8 and 31.2) and ADF (34.5 and 26.4), in water oak than shining sumac. Body weight of wethers differed between treatments, although this was not reflected in DM intake. Average daily intake values were 616 g DM, 589 g OM and 9.3 g N. NDF intake was significantly lower ($P = 0.002$) in goats-fed shining sumac than in those that consumed water oak (192 versus 330 g). Daily fecal output of all components was higher ($P < 0.05$) in water oak than shining sumac-fed goats. Apparent digestibilities (%) of all components were significantly lower in water oak than shining sumac-fed animals (DM 41 versus 63, OM 42 versus 64, NDF 24 versus 37, and N 27 versus 38). Urinary N excretion, N balance and concentrations of protein, plasma urea nitrogen (PUN) and glucose in the blood were similar between diets, averaging 2.6 g N per day, 0.45 g per day, 85.5 mg/ml, and 14.1 mg/dl, respectively. The results of this trial suggest that shining sumac is utilized better by goats than water oak. The use of dried leaves in this experiment may have led to possible negative effects on nutrient characteristics that animals consuming fresh leaves may not experience.

Keywords: Goats; Shining sumac; Water oak; Digestibility; Nitrogen

1. Introduction

Rangeland grazing areas of the southwestern United States vary greatly in the quantity and quality of available forage. While abundant good quality forage may be present during periods of optimal climatic conditions, these areas also possess forage and shrub species that are considered poor quality due to the presence of antinutritive factors such as phenolic compounds and tannins. Tannins act to bind dietary protein; decreasing its digestibility (Woodward and Reed, 1989; Merkel et al., 1999). Water oak (*Quercus nigra*) and shining sumac (*Rhus copallina*) are two examples of shrub species present on grazing or woodland areas. Goats are known for their ability to consume tannin-containing brush and have the ability to utilize forage and shrub species that contain tannins and phenolic compounds at levels that prohibit their

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selection as feeds by sheep or cattle. Goats have been used to control or eliminate brush and other undesirable forage species from pasture lands and to rehabilitate pastures (Luginbuhl et al., 1999).

The objective of the present study was to evaluate dry matter intake and dry matter and protein digestibilities of water oak and shining sumac leaves when fed alone to Alpine goat wethers.

2. Material and methods

2.1. Animals and diets

Eight Alpine wethers (8–9 months of age, 27.5 ± 1.10 kg BW) were randomly assigned to provide an equal number of animals consuming either shining sumac or water oak leaves on a free choice basis as a sole diet. Mature tree leaves of both species were obtained from the Dale Bumpers Small Farms Research Center, Booneville, AR, USA and transported ~400 km to Langston University, Langston, OK, USA for the feeding trial. Due to the distance involved, it was not possible to feed fresh leaves each morning and, thus, the total amount of leaves necessary for the trial were harvested at one time and dried. Tree leaves were harvested by hand with whole water oak leaves taken whereas shining sumac leaflets were hand-stripped from the rachis. Leaves were then dried for 24 h in a forced-air oven at 46–49°C prior to shipment to Langston University. Animals were housed in digestibility crates and had free access to water and mineral block. Goats were dewormed prior to starting the trial. Tree leaves were fed once daily in the morning for ad libitum consumption. During the trial, daily orts averaged 26% of the total DM fed (S.E. = 4.8).

2.2. Sampling and analyses

A 14-day adaptation period was followed by a 4-day total fecal and urine collection. Orts were weighed each morning for intake calculations and a subsample taken and composited by animal for the period. Total fecal output was recorded daily and a 10% aliquot taken, composited by animal and frozen. Urine was collected in plastic buckets and total volume was recorded each morning with 10% taken, composited by animal and frozen. Feed was sampled daily at feeding and composited. Feed, orts and fecal samples were later dried at 55°C in a forced-air oven for 48 h. Dried feed, orts, and feces were ground in a Wiley mill to pass through a 2 mm screen. Urine samples were freeze-dried and DM recorded prior to N analysis. Blood samples were taken via jugular venipuncture on day 1 and 2 of the collection period into vacuum tubes containing sodium heparin (Becton Dickinson, Rutherford, NJ). Tubes were immediately chilled in an ice bath and centrifuged at $1500 \times g$ at 4°C for 20 min. Plasma was transferred to labeled tubes that were then stored at −20°C until analysis.

Feed, orts and fecal samples were analyzed for DM, OM (AOAC, 1984) and NDF, ADF (filter bag technique; Ankom Technology Corp., Fairport, NY, USA) and N (Technicon Instruments, Tarrytown, NY, USA). Freeze-dried urine samples were analyzed for N (Technicon Instruments, Tarrytown, NY, USA). Plasma samples were analyzed for total protein, plasma urea nitrogen (PUN) and glucose concentrations colorimetrically (Technicon Instruments, Tarrytown, NY, USA). During the study one animal died in the water oak group to a cause unrelated to diet, resulting in three animals on this treatment.

2.3. Statistical analysis

Experimental data were analyzed as a completely randomized design using the General Linear Model procedures of SAS (1989). Least-square means were calculated due to differing numbers of animals between the two treatments. A 0.10 level of probability was used to determine statistical differences between treatment means.

3. Results

3.1. Tree leaf chemical composition

Chemical composition (%) of the fed tree leaves revealed similar amounts of DM, OM, and N in the two species, but higher cell wall constituents, NDF and ADF, in water oak (Table 1). Low NDF and ADF concentrations in shining sumac indicate a higher level of cell solubles and potentially higher digestibility than water oak.

Table 1
Chemical composition of shining sumac and water oak leaves fed to goat wethers

Component	Shining sumac	Water oak
DM (%)	92.8	89.4
OM (%)	94.1	95.9
NDF (%)	31.2	54.8
ADF (%)	26.4	34.5
N (%)	1.42	1.54

3.2. Intake and fecal output and digestibility

Whereas wethers consuming shining sumac were heavier ($P = 0.058$) than those consuming water oak, daily intakes of DM, OM, and N did not differ significantly between diets (Table 2). NDF intake was lower ($P = 0.002$) in goats fed shining sumac than those consuming water oak. Daily fecal output of all components was higher ($P < 0.05$) in water oak than shining sumac-fed goats. Differing fecal outputs, coupled with similar intake values for DM, OM, and N, led to lower apparent digestibilities of these components in water oak-fed animals. The higher NDF intake seen in the water oak treatment coupled with higher ($P < 0.001$) fecal NDF levels led to a lower apparent NDF digestibility ($P = 0.05$) than that seen with shining sumac.

3.3. Urinary N output, N balance and blood parameters

Urinary N output (g per day) and N balance (g per day) were not significantly different between the two treatments (Table 2). No statistical differences were noted in blood metabolites between the two treatments (Table 3).

Table 2
Feed intake, fecal output, apparent digestibility and nitrogen balance of goat wethers fed either shining sumac or water oak leaves

Component	Shining sumac	Water oak	S.E.	*P*-value
Total intake (g per day)				
DM	615	617	61.1	
OM	585	593	56.2	
NDF	192	330	16.7	0.002
N	8.3	10.3	0.97	
Intake (g/kg $BW^{0.75}$ per day)				
DM	48.9	54.5	4.52	
OM	46.5	52.4	4.11	
Fecal output (g per day)				
DM	228	365	21.5	0.007
OM	208	343	19.7	0.005
NDF	120	253	11.9	0.0005
N	5.1	7.5	0.65	0.05
Digestible intake (g per day)				
DM	387	252	42.4	0.08
OM	377	249	38.9	0.07
NDF	72.1	77.1	10.5	
N	3.2	2.7	0.47	
Apparent digestibility (%)				
DM	62.6	40.9	1.39	0.0001
OM	64.1	42.1	1.21	0.0001
NDF	37.0	23.5	3.57	0.05
N	38.0	26.6	2.71	0.03
BW (kg)	29.2	25.4	1.10	0.06
Urine N (g per day)	2.4	2.8	0.50	
N balance (g per day)	0.8	−0.1	0.56	

Table 3
Total blood protein, plasma urea nitrogen and glucose concentrations in goat wethers fed shining sumac or water oak leaves

Component	Shining sumac	Water oak	S.E.
Blood protein (mg/ml)	84.9	86.1	2.33
PUN[a] (mg/dl)	15.9	12.3	4.37
Glucose (mg/dl)	58.9	59.2	3.38

[a] PUN: plasma urea nitrogen.

4. Discussion

Dry matter intakes of goats in this trial were similar to those recorded by Silanikove et al. (1997) for goats fed *Quercus calliprinos* (664 g per day) as a sole diet. Nastis and Malechek (1981) and Dick and Urness (1991) fed goats diets of gambel oak (*Q. gambelii*) mixed with alfalfa in different amounts. Intakes in diets with 80% mature oak ranged from 38 to 42 g DM/kg BW per day whereas a diet with 95% immature oak recorded an intake of only 23.6 g DM/kg BW per day. In the present experiment, daily DM consumption was 48.9 g/kg $BW^{0.75}$ (21 g/kg BW) for shining sumac and 54.4 g/kg $BW^{0.75}$ (24 g/kg BW) for water oak. No literature reports on consumption of shining sumac were found.

Whereas condensed tannins or proanthocyanidins were not analyzed in the present experiment, condensed tannins have been found in other oak species (Nastis and Malechek, 1981; Narjisse et al., 1995; Silanikove et al., 1997) and are likely present in both water oak and shining sumac. Condensed tannins in browse species can have deleterious effects upon digestibility through reduced ruminal digestion by acting to inhibit microbial growth, binding with microbial enzymes or forming complexes with dietary carbohydrates or proteins that are less available for digestion (Barry and Manley, 1984; Kumar and Vaithiyanathan, 1990; Reed, 1995). Condensed tannins have also been reported to reduce the proportion of essential amino acids absorbed in the small intestine (Waghorn et al., 1994).

Drying of forages prior to feeding can affect intake and digestibility and these effects may be exacerbated in the case of tannin-containing forages. For the 80% mature oak mixed diets used by Nastis and Malechek (1981) and Dick and Urness (1991), apparent DM, NDF and N digestibilities were 48.9, 26.2, and 16.9% from feeding air-dried leaves (Nastis and Malechek, 1981) and 57.8, 33.1, and 50.2% from feeding fresh leaves (Dick and Urness, 1991), respectively. Nastis and Malechek (1981) estimated that DM digestibility of oak alone was 46.7%. Intake of fresh *Calliandra calothyrsus* leaves, a condensed tannin-containing tropical shrub legume, was higher than that of wilted material, and *in sacco* DM digestibility of oven-dried and wilted leaves was less than that of fresh leaves (Palmer and Schlink, 1992). IVDMD of certain tannin-containing tropical tree legume leaves can be reduced by freeze drying, sun drying or oven drying at 40, 60 or 100°C compared to fresh, wilted leaves (Mahyuddin et al., 1988). Merkel et al. (1994) reported increased fiber levels and decreased IVDMD in samples of *C. calothyrsus* oven-dried at 60°C than in identical freeze-dried samples. Conversely, Makkar and Singh (1991) found no differences in condensed tannin, NDF, ADF or lignin concentrations in mature *Q. incana* leaves that were either fresh, shade-dried, sun-dried or oven-dried at 60 or 90°C. The authors concluded that livestock would experience similar adverse effects upon dietary digestibility consuming either fresh or dried oak leaves.

Low temperatures, 46–49°C, were used in drying tree leaves in the present trial. Temperatures above 60°C have been shown to dramatically increase insoluble nitrogen levels in orchardgrass (Goering and Van Soest, 1973). However, as noted above, temperatures as low as 40°C can affect nutritive value of tannin-containing forages. The effect of oven drying the tree leaves prior to feeding in the present experiment is unknown. Further research is needed to ascertain if tannins are playing a role in reducing digestibility and availability of nitrogen. It is possible that goats consuming fresh leaves of these species, particularly water oak, may derive more benefit than the results of the present experiment imply.

No literature reports were found for blood protein, PUN and glucose for goats consuming shining sumac and water oak. Dietary condensed tannins may act to depress PUN values compared to tannin-free diets due to a decreased availability of tannin-bound nitrogenous compounds for ruminal digestion. However, since condensed tannin levels were not determined, nor any method of deactivating them included in the trial, few conclusions can be drawn concerning the mechanism of the differences noted between the leaves and their effects upon blood metabolites. Silanikove et al. (1997) fed polyethylene glycol (PEG) to goats to bind dietary tannins from oak leaves (*Q. calliprinos*) and noted no differences in blood serum urea levels from unsupplemented animals.

5. Conclusion

Results of the present study suggest that goats utilize shining sumac better, as indicated by higher apparent DM, OM, NDF and N digestibilities, than water oak. The use of dried leaves in this experiment may have led to possible negative effects on nutrient characteristics that animals consuming fresh leaves may not experience. This may be particularly true for water oak. Condensed tannins, or other possible anti-nutritive compounds in these species, need to be quantified and their dietary effects evaluated. Further research is required using fresh leaves of these species fed to goats for extended periods of time to gauge the effects of continuous ingestion of these forages upon digestibility and production characteristics.

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